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CORROSION PREVENTION AND PROTECTIVE COATINGS FOR STEEL PILING

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SUMMARY

Nineteen paint coating systems and six flame-spray coatings were evaluated by suspending coated steel panels in Port Hueneme Harbor so that one part was continually under water, one part was in the tidal zone, and the remaining part was in the atmospheric or splash zone. Eight of these coating systems appear to merit further evaluation. The most durable system as determined by this 30-month test was a 5-coat vinylidene chloride-acrylonitrile copolymer resin, Saran, (Navy Formula No. 113). Four vinyl resin paint systems were among those meriting further study. A system consisting of a wash prime coat, an anticorrosive (red lead) coat and an aluminum-pigmented top coat was rated as the best vinyl combination tested. Other systems requiring further evaluation are a Neoprene system, a chlorinated rubber system, and a system based on a vinyl Thiokol resin blend.

The flame-spray coatings were exposed for 19 months. Sufficient change had not taken place to permit an evaluation of these systems.

INTRODUCTION

This technical note gives the results of a preliminary study of coating systems which were applied to steel panels and exposed at a corrosion dock in Port Hueneme Harbor for thirty months. The test was intended to select coatings which might be suitable for use on steel piling. Three exposure conditions were obtained: (a) atmospheric - an area where the coated specimen was not submerged but was subject to splashing of sea water, (b) tidal - an area alternately exposed to the atmosphere and submerged in sea water, and (c) submerged - an area submerged in sea water at all times. By using steel specimens 10 feet long, approximately one-third of the areas of the panels were exposed to each of the three exposure conditions. While the test conditions did not include the abrasion due to a sand-sea water slurry action to which piles are often subjected, the exposure was considered severe enough to screen out weak coating systems in a relatively short time.

Early test results indicated that some types of coating systems did fail at one or more of the above zones after a short exposure period. Thus, a group of experimental primers which were exposed at the beginning of the test period showed 50 per cent failure in nine months, and since results of this test were inconclusive they are not reported.

Two test series are included in this report: a group of nineteen panels coated with paint systems and exposed on 23 December 1952, and a group of six panels which were coated with flame-sprayed materials and exposed on 1 November 1953. The nineteen paint systems were exposed thirty months; the six flame-sprayed materials were exposed nineteen months.

TEST PROCEDURES

The panels used in these tests were 2½-inch angle-iron specimens 10 feet in length. Surfaces were sandblasted to a gray matte finish and the first or prime coat was applied immediately. All coatings in the first series (those applied and exposed in December 1952 and listed in Table I), were applied either by brushing or spraying, in accordance with the manufacturers' directions or other specifications. The flame-sprayed coatings (exposed in November 1953 and listed in Table II) were applied by specialists skilled in the use of flame-spray guns. One of the guns utilized plastics or metals in the powder form and the other gun used metals (zinc and aluminum) in the wire form.

After the coatings were thoroughly dry the coated angle-iron panels were suspended from a corrosion dock in Port Hueneme Harbor so that (a) one-third of the area was under atmospheric exposure, (b) one-third was in the tidal zone, and (c) one-third was completely submerged.

Visual inspections were made at monthly intervals, and ratings were assigned to each of the three exposure areas on the panels. Ratings were made on a scale of 10 to 0, with 10 indicating maximum protection and 0 indicating complete lack of protection. More specifically, a rating of 10 under the heading "Rusting Observed" indicates that there was no visible rust on the coated panel; a rating of 5 indicates that one-half of the coated area was still being protected against rust or that 50 per cent of the area was free of visible rust.

Ratings lower than 5 were not usually assigned, unless one area (e.g., tidal zone) of a specimen was in much worse condition than the other two areas. If two areas of the specimen rated less than 5, it was removed from the test.

Regular observations were made of fouling attachment, and in the early part of the test estimates were made of the percentage of the total area of the coated specimens affected by fouling attachment. However, in reporting the final results, the amount and type of fouling growth is discussed only briefly.

RESULTS

Ratings of "Rusting Observed," recorded in Tables I and II, were made on 29 June 1955. The extent of rusting was judged from observations of the specimens after the fouling attachment had been removed (see Figure 1).

Table I gives application data and ratings of nineteen paint systems after an exposure period of thirty months on a corrosion dock at Port Hueneme Harbor.

Table II gives application data and ratings of six flame-sprayed materials after a 19-month exposure period at the corrosion dock.

Fouling attachment on the paint coatings which remained under test after thirty months' exposure are shown in Figure 1, specimens C-1 through G-1, at left side of the photograph (lower two-thirds of the panels). Some of the coated specimens not shown in Figure 1 failed early in the exposure period and were removed from the test. A coal-tar enamel system (A-1), one of the coatings removed, failed because barnacles were able to penetrate the enamel top coat and permitted rusting of the metal. Other types of coatings were not

appreciably damaged by fouling attachment. For example, the vinyl resin coating, E-4, was covered with a heavy growth of barnacles in the tidal zone but no adverse effects were noted.

Referring to the five flame-sprayed specimens on the right side of the photograph (Figure 1), it is apparent that there was a heavy growth, barnacles and mussels predominating, on aluminum wire (W-Al) and powdered Thiokol (P-T) coatings. A medium-heavy attachment was noted on the aluminum powder coating (P-Al), but the flame-sprayed zinc metal coatings, zinc powder (P-Zn), and zinc wire (W-Zn), had acquired only a light growth, with algae predominating.

Figure 2 shows the panels after the fouling organisms had been removed.

DISCUSSION OF RESULTS

1. Coating Systems Exposed Thirty Months (Table I)

Three of these systems were considered to be low in resistance to tidal and submerged exposure conditions. These systems were coal-tar enamel, A-2; chlorinated rubber, C-2; and Wurtzilite mastic, G-1. It should be noted that the first two of these systems afforded excellent protection in the atmospheric exposure area. However, it is doubtful that coal-tar enamel would show satisfactory protection when exposed to strong sunlight. The corrosion dock at Port Hueneme is so situated that the panels are in shade most of the time. Eight of the original nineteen coatings appear to merit further evaluation. The following discussion is based on the results listed in Table I.

Coal-Tar Coatings (Systems A-1 and A-2)

Coal-tar primer and enamel system A-2 proved to be a better system than A-1, probably because the A-2 enamel was harder and not as easily damaged by fouling organisms. Apparently the unusually thick (80 to 90 mils) coal-tar enamel coatings do not present as much resistance to damage by fouling attachment as most of the other coatings. The cold-applied coal-tar paints (34Yb) were not included in the nineteen coating systems discussed in this report but will be evaluated in the first phase of the pile-driving tests.

Neoprene Brushing Compositions (Systems B-1, B-2, B-3)

System B-1 was a maintenance-type coating, consisting of a ready-mixed neoprene paint used as a primer, intermediate, and finish coat. This coating system is usually recommended for industrial atmospheric exposures and is apparently not sufficiently durable in a 4-coat application for use in sea water exposures.

System B-2 consisted of a single paint, prepared just prior to application by adding an accelerator to the remainder of the paint. This catalyzed paint was used as a primer and finish coat in a 2-coat application. A special primer has been recommended for use with System B-2, and the lack of a primer may have been partially responsible for the early failure of the system. However, both Systems B-1 and B-2 were applied as relatively thin coatings (3 mils) and this thickness was apparently not sufficient for neoprene systems to provide long-term protection for the steel in sea-water exposures. Neoprene System B-3 consisted of a coat of special primer and six coats of a catalyzed paint prepared in the same manner as B-2 paint. The 7-coat B-3 system, 9 mils thick, provided good protection for steel.

Chlorinated Rubber Systems (C-1 and C-2)

System C-1 consisting of a primer pigmented with red lead (one coat) and a finish paint pigmented with aluminum (two coats) had a film thickness of only 2 mils. However, this thin film coating afforded better protection than the 5.5-mil film produced by System C-2, which consisted of a wash prime coat, two intermediate coats, and two gray-pigmented top coats. The combination of red-lead primer and aluminum top coats appears to be a good system in chlorinated rubber vehicles.

Thiokol Rubber Systems (D-1 and D-2)

System D-1 consisted of a solvent-type Thiokol rubber primer coat and two top coats, but this thin film (1.5 mils) coating gave only a minimum protection to steel.

System D-2 was based on a reverse-phase dispersion of a Thiokol latex in a solution of a vinyl resin. This vehicle contained a higher solids content than many vinyl resin paints; consequently a higher build up per coat was obtained. Three coats of the Thiokol-vinyl resin paint gave a dried film of 7 mils, and the coating provided excellent protection in the splash and tidal zones.

Vinyl Resin Paint Systems (E-1 to E-5)

System E-1 was classed as a single-solution-type paint system, i.e. a single paint could be used as a primer, intermediate, and top coat. This simplified paint system had less protective value than vinyl systems E-3, E-4, and E-5; although it was more effective than E-2, which consisted of a primer and two aluminum-pigmented top coats.

Systems E-3, E-4 and E-5 all utilized a wash prime coat and all three gave good protection to the steel in these tests. In System E-3,

the wash prime was followed by an intermediate red lead coat and an aluminum-pigmented finish coat, and this system gave better protection to steel than other vinyl systems. System E-4 is a type of vinyl wash prime system frequently used, consisting of two intermediate or anti-corrosive coats and two top coats. The two stainless steel intermediate coats and single seal coat of System E-5 did not provide a thick coating (2 mils) but this wash prime system also gave good protection, as noted above.

Saran Resin Coating (F-1)

This system was based on a vinylidene chloride-acrylonitrile resin binder to which was added either white or orange pigment. The two colors were used alternately to provide contrast and insure better coverage per coat. Five coats were applied, giving a dried film thickness of 6 mils. System F-1 gave maximum protection to the steel in this test and no appreciable deterioration was observed in any of the three exposure areas. Fouling attachment was medium in amount, but the coating was not damaged by organisms at the end of thirty months' exposure.

Wurtzilite Mastic Coating (G-1)

System G-1 consisted of a wash prime coat, one intermediate coat and one top coat. A wash prime was used, and the remaining coats contained Wurtzilite. The 4-mil coating was not as thick as the usual mastic coating and did not provide sufficient protection to steel to merit further testing.

Varnish-Type Paint Containing Zinc Dust Pigment (H-1)

This paint contained a high percentage (by weight) of zinc dust and utilized a varnish-type binder. The 2-coat system was ineffective, but another paint containing a high percentage of zinc dust and utilizing a polystyrene resin binder has been included in the coatings to be tested on steel piling.

Inorganic Silicate-Type Paint Containing Zinc Dust Pigment (J-1 and J-2)

These silicate-binder zinc-dust-type coatings did not prove effective in protecting steel in this test. However, it was noted that the thickness was low (1.0 to 1.5 mils). A recent improvement in this type of coating provides a film thickness of 2.5 mils per coat and a curing solution is sprayed on two to four hours after the coating is applied. The improved inorganic silicate zinc-dust paint is being tested as a coating for steel piling.

2. Flame-Sprayed Coatings (Table II)

Flame-Sprayed Metals (P-Zn, P-Al, W-Zn, and W-al)

The zinc coating applied in the powder form (P-Zn) at a thickness of approximately three mils, was apparently below the critical thickness of flame-sprayed zinc metal needed for the protection of steel. With this exception, the flame-sprayed metals were giving maximum protection to steel at the end of nineteen months' exposure. The results now available do not indicate any superiority of the wire form over the powder form used in flame-spraying metals.

Efforts have been made to provide a continuous sprayed-metal coating, with maximum bonding to the steel substrate. Sharp silica sand was used in blast-cleaning. The coatings have been built up gradually by making more passes of the flame-spray gun, and relatively thick coatings have been provided. In the case of aluminum metallized coatings, a "steel bond" coat has been applied to steel piling prior to the aluminum coat.

Flame-Sprayed Organic Coatings (P-P and P-T)

The flame-sprayed polyethylene powder (P-P) coating was under test only five months when the panel was lost. At the end of five months this polyethylene coating was providing maximum protection. Flame-sprayed Thiokol (P-T), applied in powder form, was giving maximum protection at nineteen months.

CONCLUSIONS

1. Saran resin coating systems give excellent protection to steel in tidal and submerged exposures and should be used as a high-quality standard system in future investigations.
2. Four types of vinyl resin coating systems, and one vinyl resin-Thiokol blend system afforded good protection to steel. Further study of vinyl systems is needed to find combinations giving maximum protection.
3. The hot-applied coal-tar enamel coatings used in this test were not sufficiently resistant to damage by fouling organisms to justify further investigation of this type of coating.
4. Flame-sprayed materials have not been exposed long enough to show variations in their performance.

RECOMMENDATIONS

1. Eight coating systems: neoprene, B-3; chlorinated rubber, C-1; Thiokol-vinyl, D-2; vinyl resins, E-1, E-3, E-4 and E-5; and Saran, F-1; merit further study.
2. The exposure of flame-sprayed materials should be continued until some valid comparisons can be made.
3. Neoprene brushing compositions, in thicknesses of 10 mils or more, should be included in future investigations.
4. A chlorinated rubber paint system, based on a red-lead primer and an aluminum-pigmented top coat, should be included in future investigations.

TABLE I

Application data and ratings of nineteen coatings systems exposed at a corrosion dock at Port Hueneme Harbor for thirty months or until 50-per cent failure had occurred.

| Coating Code | Coating System ^{1/} | No. of Coats | Film Thickness (Mils) | Time to 50% Failure ^{2/} | Rusting Observed ^{3/} | | |
|--------------|---|--------------|-----------------------|-----------------------------------|--------------------------------|----|---------|
| | | | | | all | by | cut |
| A-1 | 34Yb-primer and hot-applied coal-tar enamel. | 2 | 80.0 | 10 months | | | removed |
| A-2 | Coal-tar enamel system similar to A-1 but having a lower penetration enamel. | 2 | 90.0 | ---- | 10 | 6 | 4 |
| B-1 | Neoprene brushing compound system. No catalyst. | 4 | 3.0 | 11 months | | | removed |
| B-2 | Neoprene brushing compound system. Accelerator added prior to application. | 2 | 3.0 | 6 months | | | removed |
| B-3 | Neoprene brushing compound system. Primer plus top coats (6). Similar to B-2. | 7 | 9.0 | ---- | 9 | 9 | 8 |
| C-1 | Chlorinated rubber system red-lead primer and aluminum top coats (2). | 3 | 2.0 | ---- | 8 | 8 | 7 |
| C-2 | Wash prime with chlorinated rubber intermediate coats (2) and gray top coats (2). | 5 | 5.5 | ---- | 10 | 6 | 7 |
| D-1 | Thiokol rubber primer and top coats (2). | 3 | 1.5 | 3 months | | | removed |
| D-2 | Combination Thiokol rubber and vinyl resin. | 3 | 7.0 | ---- | 9 | 9 | 7 |
| E-1 | Vinyl resin system. Single solution-type. | 4 | 4.0 | ---- | 9 | 7 | 7 |
| E-2 | Vinyl resin system. Primer and aluminum pigmented top coats (2). | 3 | 2.5 | 13 months | | | removed |

TABLE I
(continued)

| Coating Code | Coating System ^{1/} | No. of Coats | Film Thickness (mils) | Time to 50% Failure ^{2/} | Rusting Observed ^{3/} | | |
|--------------|---|--------------|-----------------------|-----------------------------------|--------------------------------|-----------------|-----------------|
| | | | | | a ^{4/} | b ^{4/} | c ^{4/} |
| E-3 | Vinyl resin system. Wash prime, red-lead intermediate coat and aluminum top coat. | 3 | 4.0 | --- | 9 | 9 | 9 |
| E-4 | Vinyl resin system. Wash prime, intermediate AC coats (2) and gray top coats (2). | 5 | 2.5 | --- | 9 | 8 | 7 |
| E-5 | Vinyl resin system. Wash prime, intermediate coats pigmented with stainless steel (2), and seal coat. | 4 | 2.0 | --- | 9 | 9 | 8 |
| F-1 | Vinylidene chloride-acrylonitrile copolymer (Formula 113). Five coats. | 5 | 6.0 | --- | 10 | 10 | 10 |
| G-1 | Wurtzillite mastic system. Wash prime, intermediate coat, and top coat. | 3 | 4.0 | --- | 7 | 5 | 6 |
| H-1 | Varnish pigmented with zinc dust. | 2 | 1.0 | 2 months | removed | | |
| J-1 | Inorganic silicate vehicle. Zinc dust pigment. | 1 | 1.0 | 7 months | removed | | |
| J-2 | Same system as J-1. | 2 | 1.5 | 13 months | removed | | |

^{1/} Primers and/or intermediate coats were not used unless specifically mentioned.

^{2/} Time elapsed (in months) before the coating system showed rusting over 50% of the area.

^{3/} Rusting observed was based on a scale of 10 to 0, with the 10 indicating no rust and the 0 indicating area completely rusted.

^{4/} a = atmospheric exposure area.

b = tidal exposure area.

c = submerged exposure area.

TABLE II

Ratings of Flame-spray coatings
after nineteen months' exposure
at Port Hueneme Harbor

| Coating Code | Material Sprayed | Average Film Thickness (Mils) | Rusting Observed ^{1/} | | |
|-----------------|---------------------|-------------------------------------|--------------------------------|-----------------|-----------------|
| | | | a ^{2/} | b ^{2/} | c ^{2/} |
| P-T | Thiokol powder | 6.6 | 10 | 10 | 10 |
| P-P | Polyethylene powder | 4.3 | Panel lost ^{3/} | | |
| P-Zn | Zinc powder | 2.9 | 6 | 8 | 8 |
| P-Al | Aluminum powder | 4.4 | 10 | 10 | 10 |
| W-Zn | Zinc wire | 5.4 | 10 | 10 | 10 |
| W-Al | Aluminum wire | 5.2 | 10 | 10 | 10 |

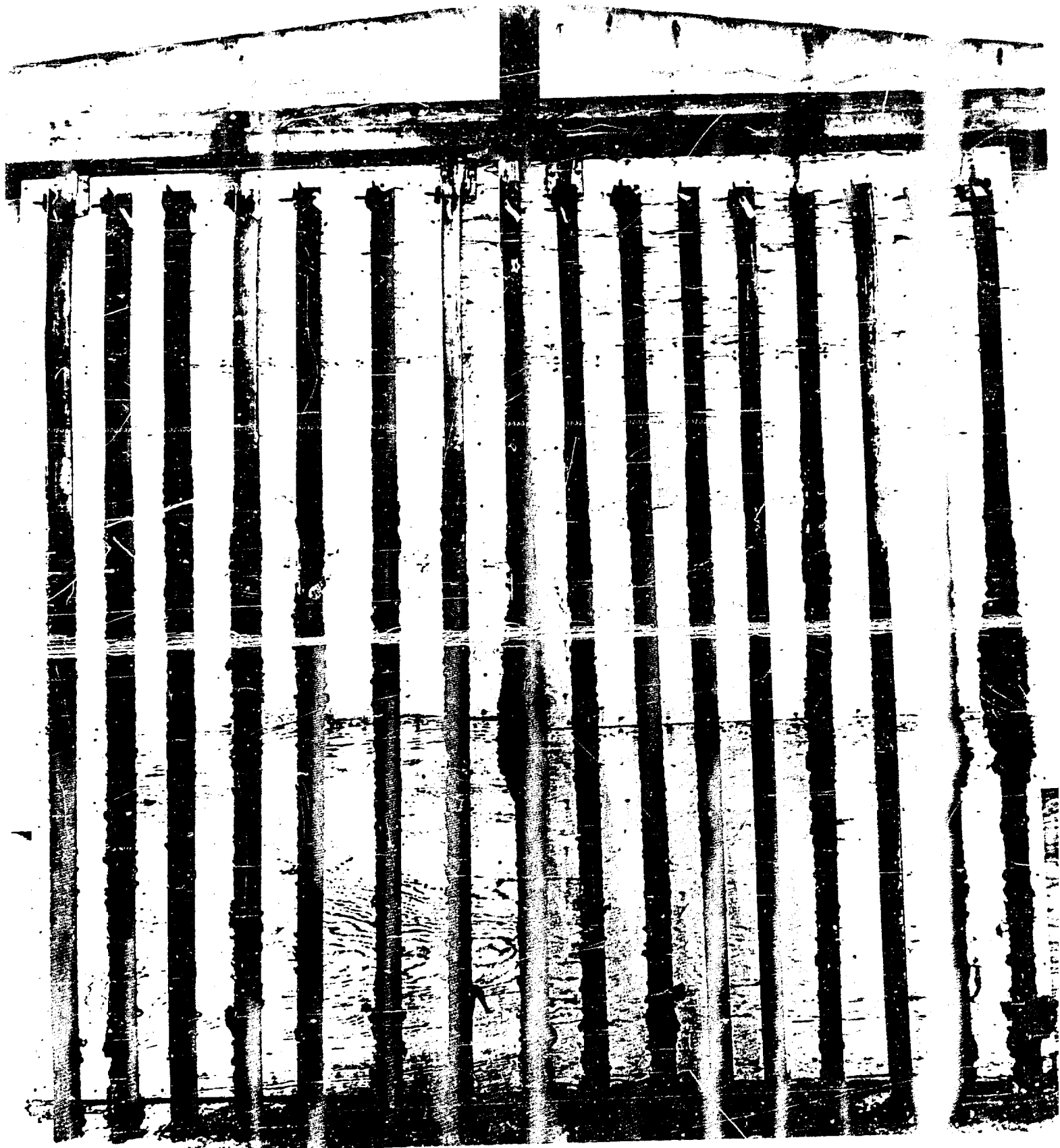
^{1/} The basis for these ratings is: 10 = no rust.
0 = completely rusted.

^{2/} a = atmospheric exposure area.

b = tidal exposure area.

c = submerged exposure area.

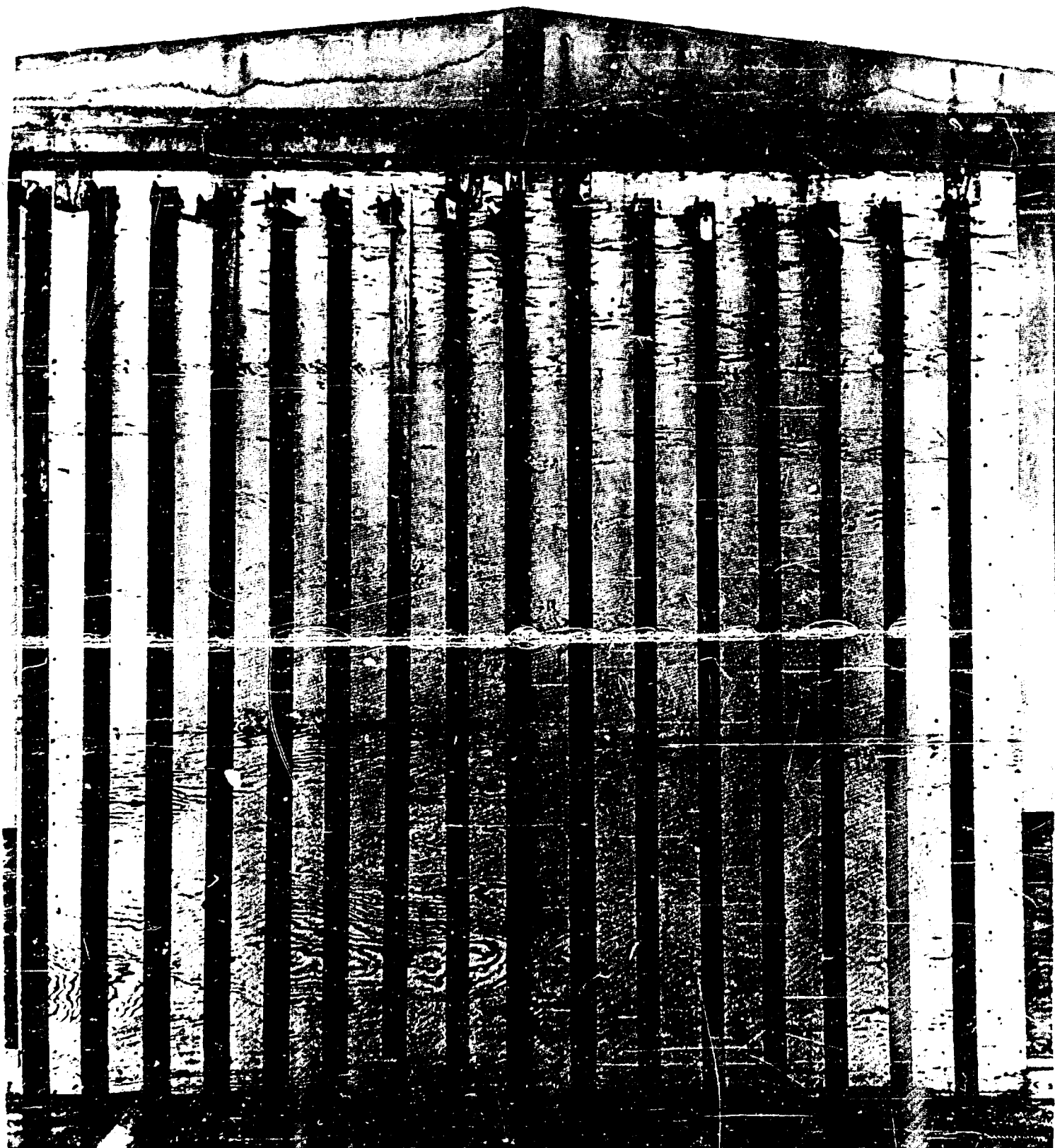
^{3/} Panel was rated 10 in all areas at the end of five months, but was lost prior to next rating period.



C-1 C-2 B-3 D-2 F-1 E-1 E-3 E-4 E-5 A-2 G-1 P-2n P-A1 W-2 M-A1 P-T

Figure 1. Angle-iron test panels with fouling attachment present after thirty months' exposure.

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C-1 C-2 B-3 D-2 F-1 E-1 E-3 E-4 E-5 A-2 G-1 P-Zn P-Al W-Zn W-Al P-T

Figure 2. Angle-iron test panels after fouling attachment had been removed.

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